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Adventures in Reliability: Heavily Censored Data

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**AIR FORCE TEST CENTER
EDWARDS AFB, CA**

May 12-14, 2015

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14. ABSTRACT At times reliability data are recorded as exact failure times on systems. This is a trivial case that is handled usually by simple textbook analysis approaches. Many times, especially in the T&E community, all that is known regarding failures is that a certain number of events have been observed during a flight. These type of data are called 'interval data' and do not equate with exact failure times. Trivial analysis approaches can severely bias MTBF estimates and 'paint a pretty picture'. In this presentation statistical techniques for handling this data are discussed.					
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412th Test Wing



War-Winning Capabilities ... On Time, On Cost



U.S. AIR FORCE

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Flight Test Failure Data



- Best case is to observe right, left or interval censored data

- Fails during a flight...that's all we know.

- Right:



- Left:



- Interval:



- Interval data happens when multiple flights occur before a failure is observed.
- We will ignore intervals this time...maybe next time.



Rehash of Rocket Motor Data



Catastrophic Missile Failures During Launch

- **20,000 missiles in inventory.**
- **1,940 field firings of the missile.**
- **From June 1997 to March 1998 there were 3 catastrophic failures of the motor.**
- ***Estimated service life = 20 years.***
- ***Saw catastrophic failures at:***
 - ***$T = 8.5, 14.2, \text{ and } 16.5 \text{ years.}$***

Olwell, D., Sorell, A. (2001), Annual Reliability and Maintainability Symposium.

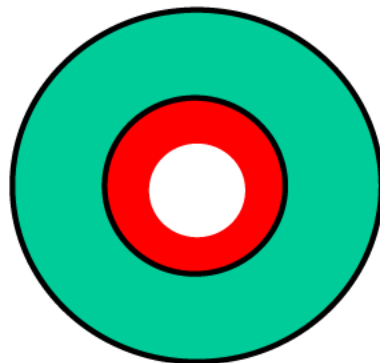


Possible Failure Causes

How do we analyze this?... →



- **Believed Failure Mechanism (acc. to NSWC-IH):**
 - Thermal cycling—caused propellant-to-case bondline AND/OR propellant-to-propellant bondline to fail.
 - Causes the surface area to increase and explosive ignition of propellant.



Motor
Crossection



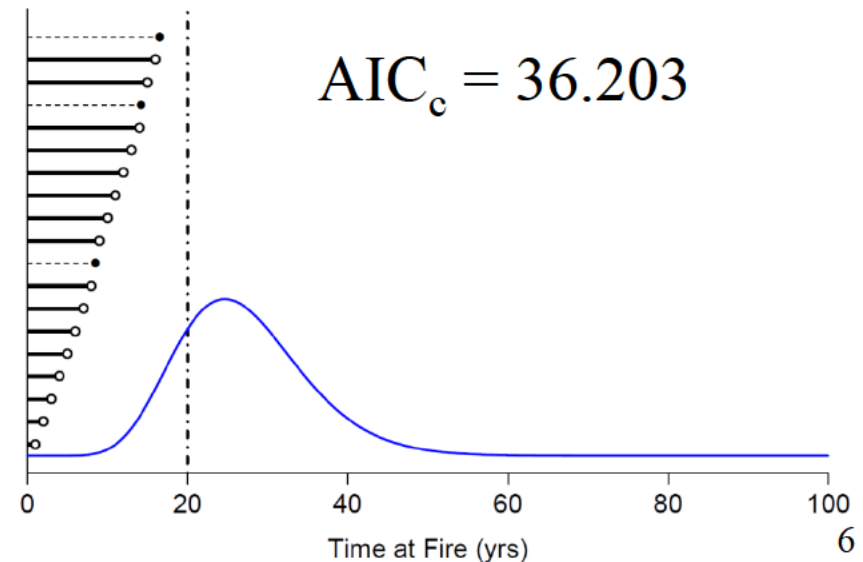
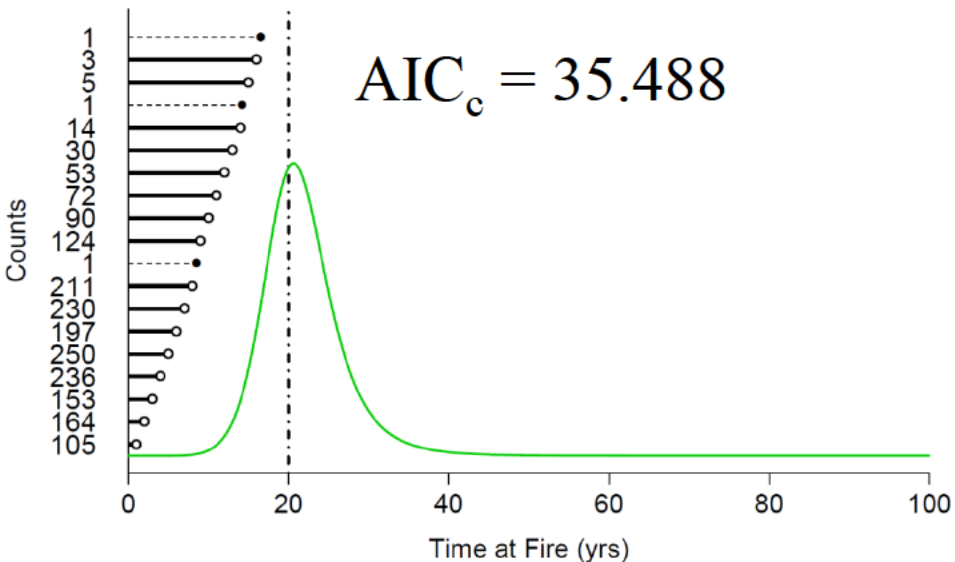
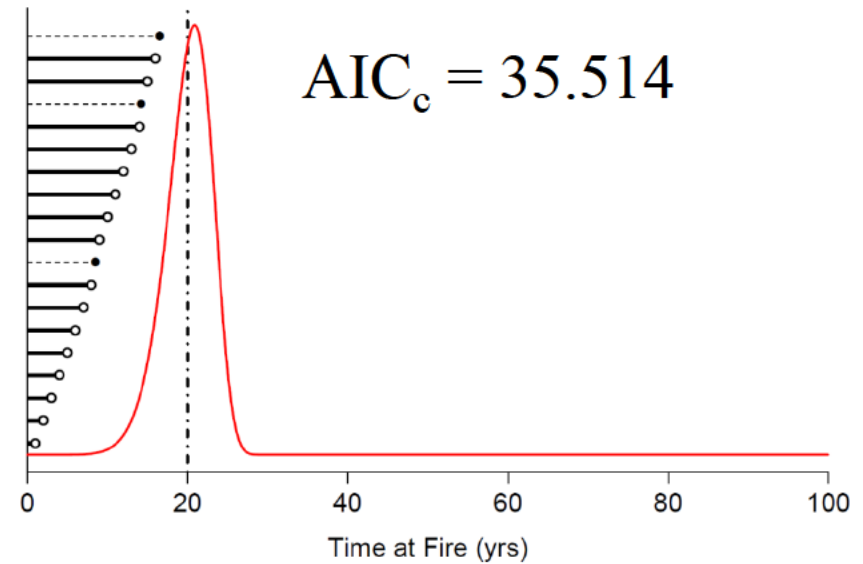
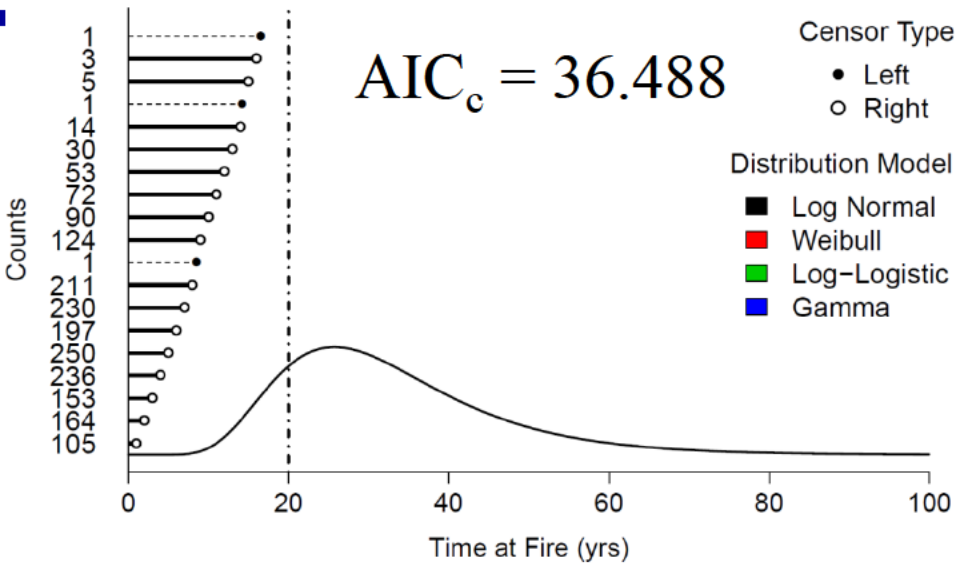
→...With one of many models. Choose your Adventure



- **Probability Models:**
 - Exponential
 - Lognormal
 - Weibull
 - Logistic
 - Log Logistic
 - Rayleigh
 - Frechet
 - Normal
 - SEV
 - LEV
 - ...
- All have descriptions of why they are useful.
- **Censoring \Rightarrow Model Fitting Difficulty**
 - Use likelihood methods...
- *Which one should we use?*
- *Does it matter?*

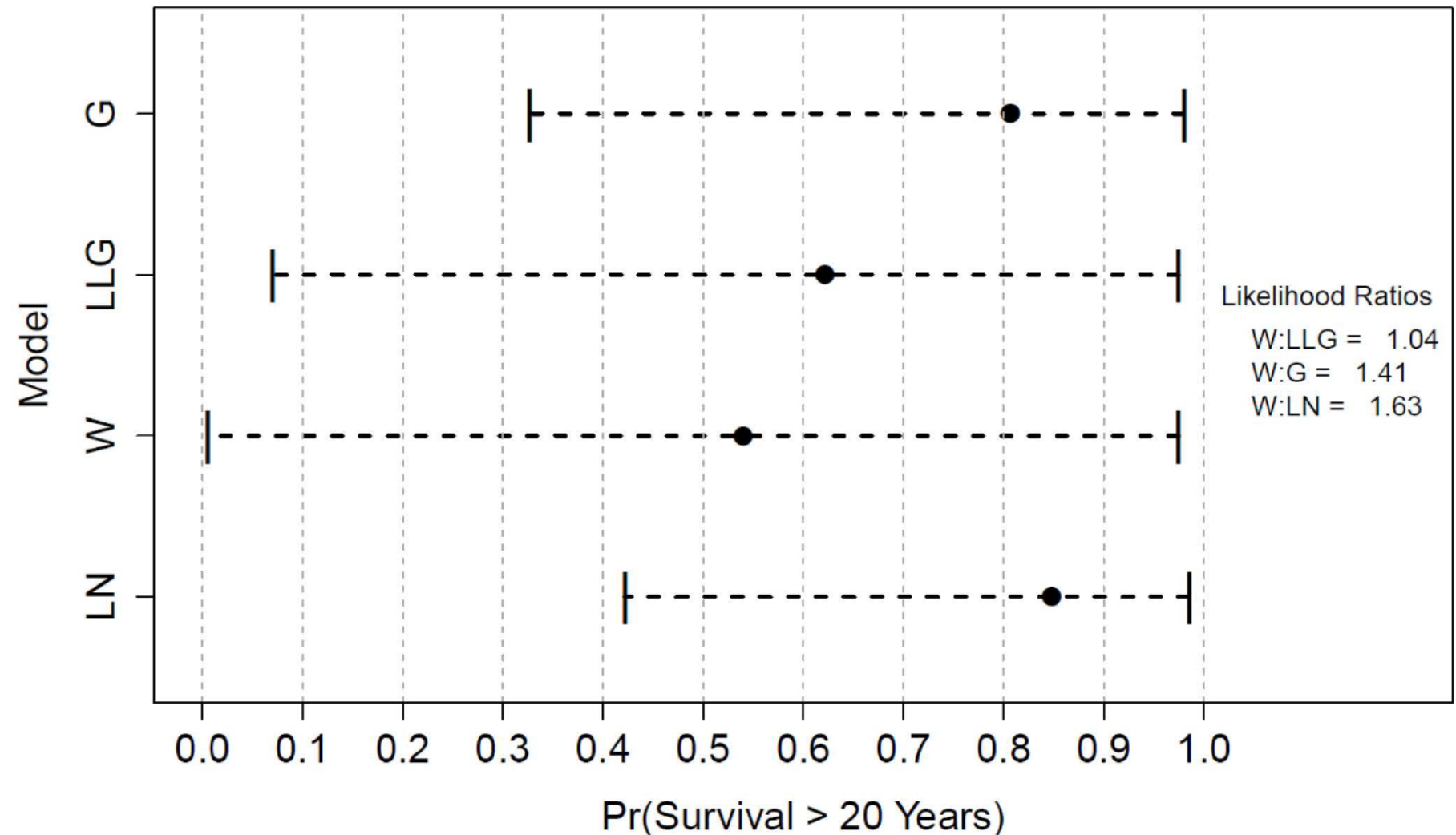


Fitted Life Models *{Best is MIN(AIC)}*





Which model would you choose? Based on Reliability Estimation and CI's





Summary



- **Stake holders on both sides of the fence may choose different models based on interests.**
 - **Uncertainty in decisions, or indecision.**
 - **Implies model selection uncertainty.**
 - **Somebody has to choose...unbiasedly.**
 - **What tool or method will they use?**
- **Who can justify their choice?**
- **MORE QUANTITATIVE RIGOR**
 - **More to come on this in the future...**